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SECTION No. 12

Producer Gas for Road Traction

By

E. A. Allcut

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PRODUCER GAS FOR ROAD TRACTION

By E. A. Allcut, *Associate Professor of Mechanical Engineering*

Introduction

With the continued and increasing consumption of gasoline for road vehicles, and the development of high-powered aircraft engines requiring large quantities of light fuel, it is evident that, in the near future, some alternative method of driving high speed light-weight engines must be devised. Much experimental work has been and is being done with the object of adapting heavy oil engines for this purpose, and while some measure of success has been achieved with large powers, the engine is generally too complicated, heavy and costly for the small powers used in road traction. When the suction gas producer reached a reasonable state of reliability and became widely used in combination with stationary gas engines, several portable types were designed and used for various purposes,[1] but in most cases these were too heavy and bulky for transport purposes, and moreover required large quantities of water for cooling and cleaning the gas before entering the engine.

In marine and motor boat work, where the conditions were not so exacting, some fairly satisfactory suction plants using anthracite, charcoal or coke were made, and during the war the increasing scarcity and high cost of gasoline in England and Europe led to the design and construction by Col. D. J. Smith of a small suction gas plant, which was mounted on a motor truck. This is claimed to have given satisfactory results, and the design was developed and improved after the war, when the author had the opportunity of inspecting and testing a "Smith" producer which was connected up to a stationary four-cylinder gasoline engine ($3\frac{3}{4}'' \times 5''$) coupled to a Froude dynamometer, and upon this plant a considerable amount of experimental work was done during the spring of 1920.

Observations were also made under running conditions on a 3-ton motor truck, a Ford car, and a motor boat equipped with this type of power generator.

A further development along similar lines (the "Parker" producer)

[1]See Robson, "Power Gas Producers," (1908), p. 125. Also Rambush, "Modern Gas Producers," p. 338.

was tested on the road in the fall of 1920, and although encouraging results were obtained on both designs, they were not sufficiently conclusive and reliable to justify the application of this type of generator on a commercial scale. It was considered, however, that the difficulties experienced would ultimately be overcome by improved designs and that the ultimate success of the gas producer in this connection was a matter of time and experience.

Since that time further developments have taken place, and Messrs. Thornycroft of Basingstoke, England, have put on the market a standard truck in which a suction gas producer is incorporated.[2] The Hungarian State Railway has developed a similar plant,[3] and several automobile firms in France, Germany and Central European countries have also adopted the gas producer system. Several of these systems have been described in the press[4] during the past few years, but although slightly different in detail, they are all similar in principle.

It should be recognized from the outset that this system is unlikely to be suitable for passenger cars, but its main field of application will probably be in truck and traction work, where the conditions of working and the care and attention available are much more conducive to its successful operation.

PRACTICAL DESIGNS AND TEST RESULTS

The size of gas producer employed for traction work is much smaller than that generally used for stationary plants. The firebrick or corundum lining usually has an inside diameter of from 10 to 12 inches, and the overall size of the producer is generally about 14 to 18 inches diameter (or square) and 2½ to 4 feet high, varying with different designs. Some producers have shaking grates and mechanical fuel feed, but for traction purposes it is advisable to have as few moving parts as possible. In some cases wet scrubbers are used for cleaning and cooling the gas, but although these are generally more effective than dry scrubbers both for cleaning and cooling, their cost, complication, and the extra cooling water required are decided disadvantages, and therefore an air cooled scrubber is preferable.

The advantage of the suction over the pressure system of gas generation is that there is no leakage of poisonous gas into the atmosphere, all leakage being that of air into the plant. Such leakage, of course, dilutes the gas and therefore all joints should be made and kept tight.

Ample arrangements must be made for the separation and collection of

[2]Times (London) Trade Supplement, Sept. 2nd, 1922.

[3]Automobile Engineer, May, 1923.

[4]*Cf.* "Mail and Empire," Toronto, Jan. 23, 1924.

dust and moisture from the gas, as considerable difficulty was experienced in the earlier installations with moisture collecting on the sparking points when starting up, and also with fouling of plugs, valves, and lubricating oil in actual running.

Usually no great difficulty is experienced in starting up from cold, but during this operation the fire is generally blown up by a hand-propelled fan, and arrangements must be made to exhaust the gas generated during this operation, on account of the CO and CO_2 present in the gas.

A great disadvantage of the suction system is its comparative inflexibility. Under constant load and speed a suction plant runs very well, but when the engine is slowed up or stopped, the fire cools down and the gas subsequently supplied is of poor quality. This is particularly objectionable in traffic or hilly country. Messrs. Thornycroft supply an exhauster to keep the fire in condition and in other cases the clutch is allowed to slip when running slowly in traffic. This keeps the engine running at a high speed and enables it to pick up better when the load comes on again. In this connection it is important that the water or steam supplied to the producer shall be adjusted automatically to maintain a constant ratio of air to water supply, as otherwise an excess of steam will be obtained at light loads or slow speeds, thus further cooling down the fuel bed and producing poor gas.

The fuels generally employed are anthracite, coke and charcoal, all of which are usually satisfactory, but the power given out by an ordinary gasoline engine running on suction gas is about 20 per cent. less than that obtained from liquid fuel. For commercial applications, therefore, it will either be necessary to increase cylinder dimensions, or to reduce the rated load of the truck. One difficulty frequently met with in gas producer work is the formation of clinker which obstructs the flow of air through the fuel, produces poor gas and finally stops the plant. Non-clinkering fuels should therefore be used and arrangements made to clean and consolidate the fire during running. In some cases the shaking of the vehicle may do this, but much depends upon the design of the producer, the method of feeding the fuel and the nature of the fuel used.

It may be pointed out that generally the fire hazard is less with solid than with liquid fuels, and that as there is no danger of "pinking" or detonation, higher compressions may be employed with safety, but in the latter case, although the efficiency may be increased, starting will be more difficult.

The fuel consumptions generally given are for running tests over measured distances, but it should be noted that the fuel consumption continues (to a much less extent) when the truck is stopped. Con-

sumption over measured distances, therefore, do not form true comparisons between gasoline and gas producer trucks, but as in most instances these are the only figures available, they will be used to give some idea of the fuel economy of these vehicles under running conditions.

No description will be given of the details of these plants as they are adequately described and illustrated in the articles enumerated in the footnotes.

"Parker" Plant[5]

Guaranteed consumption of foundry coke for 3-ton truck fully loaded is 3 lbs. per mile over 100-mile run. Gasoline consumption of same truck is 0.17 Imperial gallons per mile.

The water used for gas making in all these plants is about half the weight of fuel consumed.[6]

"Smith" Plant[7]

Col. Smith gives the following comparison in fuel consumption:

	5-ton steam truck	5-ton gasoline truck	5-ton producer gas truck
Gross load tons	12	9	9.5
Lbs. fuel per mile	14	1.33	1.56
Lbs. fuel per *nett* ton per mile	2.8	.26	.312

When the difference in cost between gasoline and the various solid fuels is taken into account, it is evident that the cost of fuel for running a producer gas truck is very low.

Thornycroft Plant

Road tests taken over a 28-mile run at 12-13 miles per hour on a 4-ton truck:

Anthracite.....lbs. per mile 2.51 Water used.....1.61 lbs. per mile
Charcoal..... " " " 2.9 " " .....1.25 " " "

The charcoal is produced in the works of Messrs. Thornycroft at Basingstoke (England) by running the exhaust gases from the gas

[5]See "Automotive Industries," Sept. 8-15, 1921, and "Engineering," June 17th, 1921.

[6]Proc. Inst. Mech. E., April 28th, 1911.

[7]See "Producer Gas for Motor Vehicles," D. J. Smith, Journal Inst. Aut. Eng., Jan. 8th, 1920. Also "Engineering," vol. 109, pp. 59 and 92, and "Automotive Industries," Sept. 8-15th, 1921.

engines in their power station, through an airtight steel box into which the waste wood or other substances to be carbonized are placed.

The analysis of gas obtained varies considerably with the type of plant, conditions of fire, water supply, etc., but Table 1 gives a number of analyses obtained under running conditions from "portable" gas producers.

TABLE 1

Load	Fuel	CO_2	O_2	CO	H_2	CH_4	N_2	Cal.[8] Value nett	Remarks
Stationary	A	6.0	2.4	13.6	27.5	0.4	50.1	130	load 10 H.P.
engine with	A	8.0	0	12.0	36.0	0	44.0	145	no load
brake	C	6.8	2.0	21.6	26.4	0	43.2	150	5 min. after starting engine
	C	6.8	6.0	9.2	29.0	0.4	48.6	119	25 min, after starting engine
	A	10.0	1.6	6.4	25.6	0.8	55.6	104	no load
	A	6.0	2.4	13.6	27.5	0.4	50.1	130	load 10 H.P.
4-ton truck on road	A	7.8	1.3	18.8	16.6	1.8	53.7	130	2-ton load—full throttle
		4.0	3.5	19.5	23.5	2.3	47.2	157	Gas temp. 760° C.
		1.6	0.5	29.5	15.5	4.6	48.3	190	" " 1150° C.

It will be seen from this table that the net calorific value of the gas varies from 104 to 190 B.T.U. per cu. ft. and averages about 130. This is suitable for internal combustion engines, but anything below 100 B.T.U. may be considered too poor for road traction.

TORONTO EXPERIMENTAL PLANT

This gas producer was designed for experimental work so that the effects of different variables on the quality of gas and efficiency of plant might be studied.

It consists (Fig. 1) of a cast iron shell and top cover, furnished with the ordinary fuel hopper valve and poking holes. This is supported on a

[8]The Nett Calorific values used for the various gases are average N.T.P. values—CO=342, H_2=290, CH_4=955 B.T.U. per cubic foot. See Rambush, "Modern Gas Producers," p. 72.

NOTE.—A=Welsh Anthracite, C=Peat Charcoal.

Properties of Peat Charcoal used:

Moisture.....5.65% Volatiles....31.75%

Ash.....9.43% Sulphur..... .58% Total Carbon...64.87%

Cal. Value (B.T.U. per lb.) Gross 11463. Nett 11209.

mild steel ashpit provided with a dropping grate and a plate for supporting the firebrick linings. The latter consist of fireclay tubes each 19 inches outside diameter and respectively 15, 12, 10 and 8 inches inside

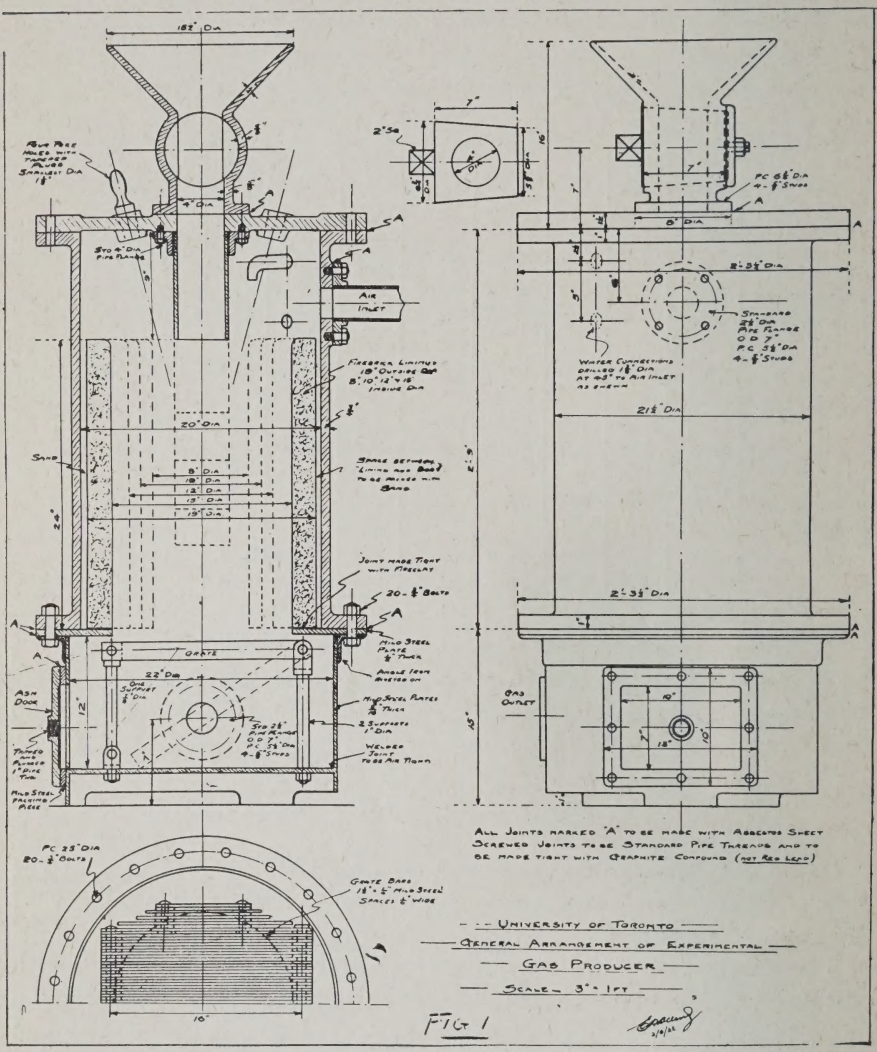

FIG. 1.

diameter. Tubes of different lengths may be screwed into the flange at the top to vary the depth of fuel bed by steps from 8 to 24 inches. The air is supplied through a measuring nozzle by a motor driven Roots blower and the piping is so arranged that air can be delivered to

the top or bottom of the producer at will, giving an up or down draft producer as required (Fig. 2).

The water supply is obtained from a tank suspended from a spring

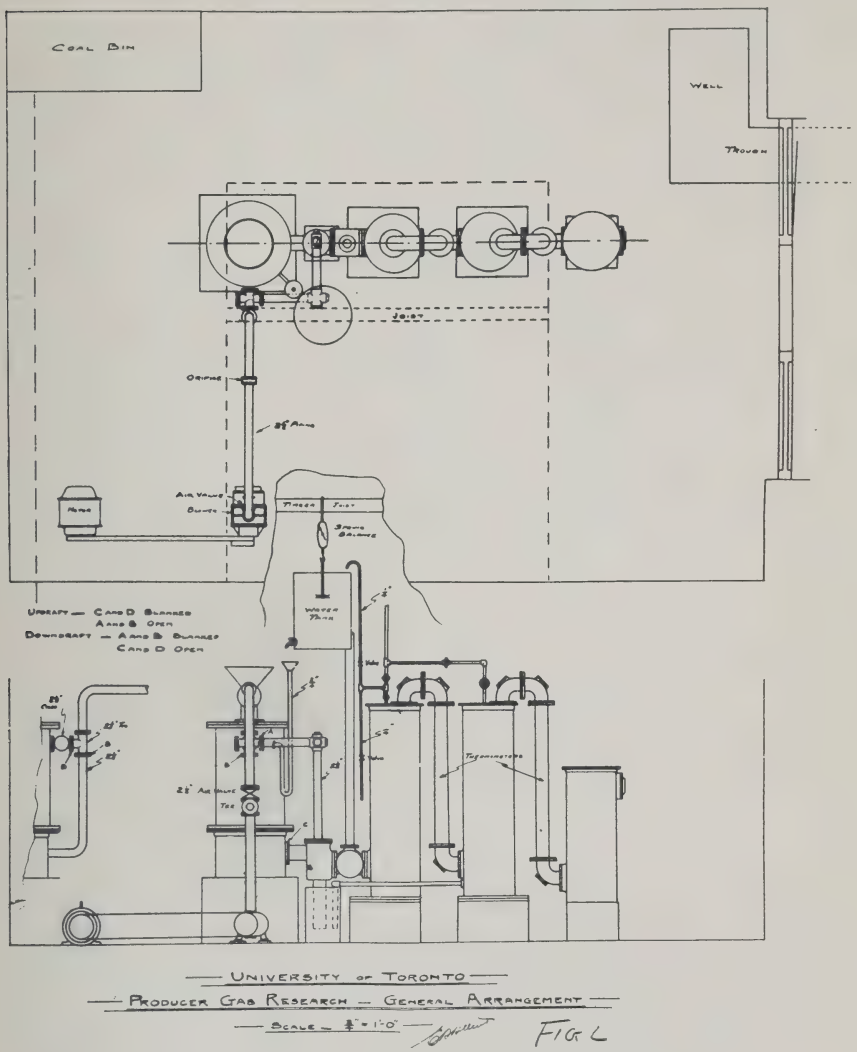

FIG. 2.

balance, and the temperature of gas leaving the producer is measured by means of a calibrated thermocouple.

With these arrangements the effect of the following variables may be investigated on producers of small size:

(*a*) Direction of draft (up or down).
(*b*) Nature of fuel.
(*c*) Diameter of fuel bed.
(*d*) Depth of fuel bed.
(*e*) Velocity of air supply.
(*f*) Ratio of air to water supply.

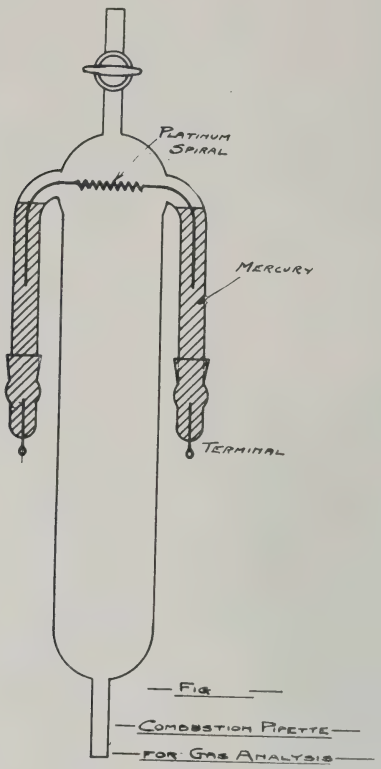

FIG. 3.

Samples of gas for analysis were taken from the pipe connecting the producer to the scrubber, and these samples were analysed in a gas analysis apparatus devised by the U.S. Bureau of Mines.[9]

On account of the use of water in the combustion pipette some trouble was experienced with the connections to the platinum spiral. The points where the copper leads were connected to the platinum frequently became hot, cracked the glass tubes in which the wires were sealed and caused leakage. Several other forms of pipette were tried

[9]See Bulletin No. 42 Bureau of Mines, "The Sampling and Examination of Mine Gases and Natural Gas," p. 43, Fig. 17.

and finally that shown in Fig. 3. was found to be satisfactory In this pipette no solid joint was used, but the copper leads were sealed into the glass arms, which were filled with mercury and the two ends of the platinum spiral also dipped into the mercury, thus giving good contact. The percentage of CO present in the gas was obtained by passing the gas (after absorbing CO_2, O_2 and heavy hydrocarbons) successively through old and new solutions of Cuprous Chloride. The "bubbling" pipettes provided for this absorption were very satisfactory and con-

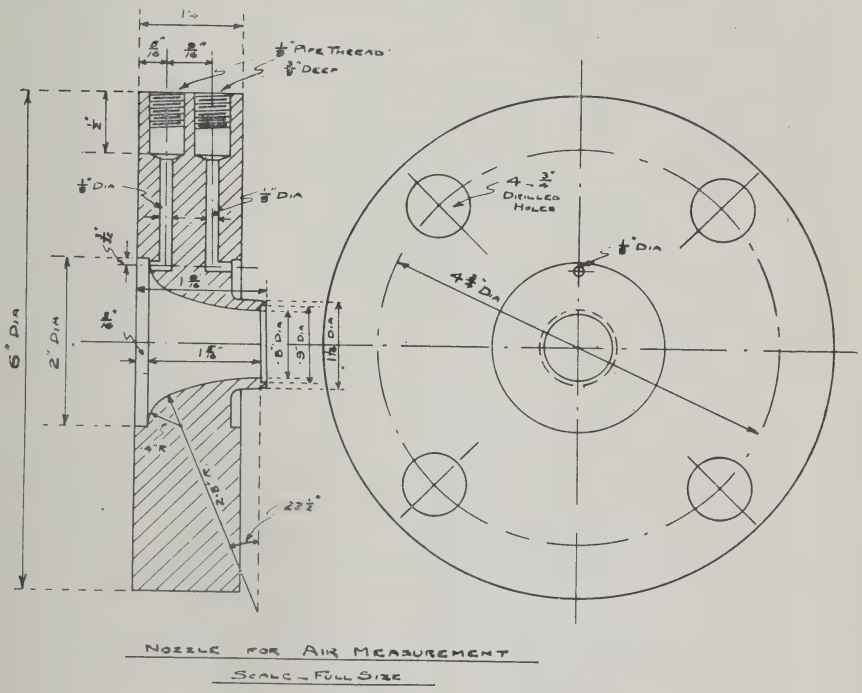

FIG. 4.

siderably reduced the time required as compared with ordinary pipettes.

The volume of air delivered per hour to the producer was calculated from the drop in pressure across the nozzle shown in Fig. 4. The contour of the nozzle conforms to the curve of the Verein Deutsche Ingenieure.[10]

An approximate delivery curve (Fig. 5) was worked out for experimental purposes, but the actual calculated values given in the tables were worked out from Reavell's formula in each case.

The gauge used for indicating the fall of presssure across the orifice was a direct lift gauge in which the position of the starting tube is ad-

[10]See Reavell on "Air Compressors," Inst. Mech. Eng., Nov. 24th, 1922.

justed by a vertical micrometer screw. This type of gauge has been previously described.[11] The alcohol used in the gauge had a specific gravity of .823 at 80° F.

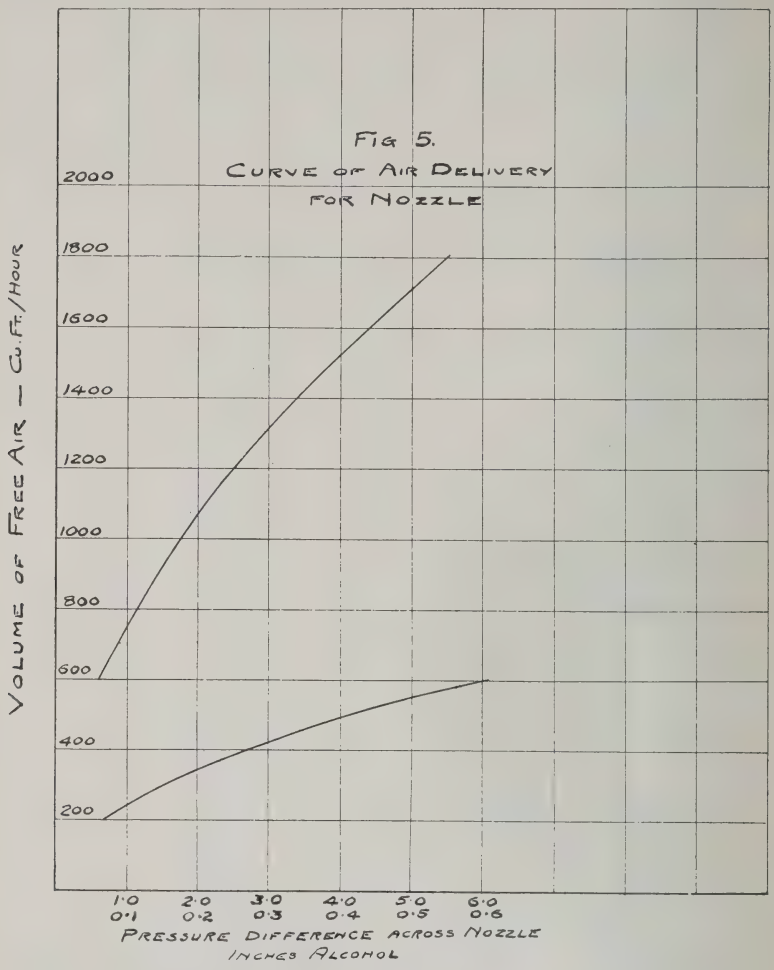

FIG. 5.

TEST RESULTS

The first series of experiments was undertaken to investigate the suitability of down draft producers for portable plants of small size. One of the chief difficulties in connection with the use of gas for power

[11]See University of Toronto Engineering Research Bulletin No. 2, pp. 50 and 58 (Fig. 13).

production is that of cleaning the gas and separating out the volatile matter before the engine cylinder is reached. With bituminous coals and other fuels rich in volatile matter this difficulty makes the use of such fuels impossible in a small plant, and therefore narrows considerably the field of choice as far as solid fuels are concerned. Anthracite is expensive and limited in distribution, and suitable coke cannot always be obtained, while bituminous fuels are widely distributed and may usually be obtained at reasonable prices. The down draft producer has been used in large sizes with a fair amount of success, and if it could be successfully adapted to small sizes, the problem would be simplified considerably.

An attempt to apply the down draft principle to a small gas producer is made in the "Stewart" plant,[12] but what measure of practical success has been obtained with this design is not known to the writer. In this instance a side chamber is used to distil off the volatile matter from the fuel and this volatile matter is then caused to pass through the hot bed of fuel in an ordinary up-draft producer. The down draft principle, therefore, is only partially employed in this case.

The experiments herein described were made on fuels containing little or no volatile matter, in order to eliminate complications as far as possible in the preliminary stages.

The quantity of water used during each test was obtained from the readings of a calibrated spring balance from which the water tank was suspended, but in addition to this, the quantity of water vapour entering the producer with the air was also calculated from the readings of a wet and dry bulb thermometer, and the total water feed was considered to be the sum of these two components plus the small quantity of water distilled from the fuel.

In all tests no readings were taken until the expiration of 1½ to 2 hours after lighting the fire, this time being allowed for conditions to become steady before each test started.

Tests Nos. 1 to 5 (Table 2) were made upon Anthracite I having the following characteristics:

Ash	16.6%
Volatile matter	17.9%
Calorific value	13,360 B.T.U. per lb.
Specific gravity	1.417
Weight per cubic foot coal as used	44.2 lbs.

The anthracite used for tests 6 to 13 was a new consignment intended to be of similar quality to that previously supplied, but actually it had a much greater ash content and its calorific value was lower than that of Anthracite I:

[12] "Automotive Industries," Sept. 15th, 1921.

Ash.....22.3%
Volatile matter..... 8.3%
Calorific value.....12,400 B.T.U. per lb.
Specific gravity..... 1.43
Weight per cubic foot as used.....43.5 lbs.

From these figures 1 cubic foot of solid anthracite weighs 88.5 lbs., and as the actual weight of coal present was 44 lbs., it follows that there were about 50% of voids present in the fuel bed, neglecting the space taken up by the ash in the lower parts of the furnace.

Tests 1 to 13 were made with different rates of air supply, and various ratios of water to air in order to ascertain the most favourable conditions for a 12-inch diameter furnace and the best quality of gas obtainable under these conditions.

Tests Nos. 14 and 15 were made on peat charcoal supplied by the Department of Mines, Ottawa. The weight of this was 24 lbs. per cu. ft., its calorific value, 11,720 B.T.U. per lb., and ash content 9.3%.

In all tests the fuel depth used was 24 inches.

TABLE 2.

Fuel	Anthracite No. I			
Test No	2	3	4	5
Fire lighted	9-10	9-15	9-5	9-10
Test started	11-30	10-45	11-0	11-0
Test stopped	4-30	3-45	4-0	4-0
Duration of test—hours	5.0	5.0	5.0	5.0
Barometric pressure—ins	29.71	29.82	29.71	29.74
Pressure of air entering producer—ins. water	5.0	3.4	2.6	7.22
Pressure drop in air nozzle—ins. alcohol	1.82	1.145	.586	2.72
Air temperature to nozzle °F.	84	88	86.5	92
Atmospheric air—dry bulb °F.	80	85.3	84.7	90
" " —wet bulb °F.	74	78.6	78.5	80.7
Humidity per cent	75	74	75.7	67
Air used per hour—cu. ft	1020	800	576	1242
Water in air per hour—lbs	1.11	1.07	.786	1.745
Water from tank per hour—lbs	7.0	5.70	4.45	8.40
Water from coal per hour—lbs	.55	.13	.065	.135
Total water to producer per hr.—lbs	8.66	6.90	5.30	10.28
Water used per lb. coal—lbs.[13]	1.095	1.025	1.07	1.22
Coal used per hour—lbs.[13]	7.9	6.725	4.95	8.43
Moisture in coal—per cent	7.0	2.0	1.3	1.6
Ash in coal—per cent	16.1	13.5	17.3	19.5
Gas Analysis: CO_2 per cent	9.9	9.3	10.4	11.7
(Average) O_2 "	1.0	1.1	.7	1.1
CO "	14.9	13.9	13.1	11.8
H_2 "	11.0	20.1	9.9	4.9
CH_4 "	.3	.5	.8	1.3
N_2 "	62.9	55.1	65.1	69.2
Higher Cal. Value—B.T.U./cu. ft	116	122	87	71.1
Lower Cal. Value—B.T.U./cu. ft	84.5	110	81	67.0

[13]Probably incorrect on account of accumulation of ash in fire.

TABLE 2—(*continued*)

Fuel	Anthracite No. II					
Test No	6	7	8	9	12	13
Fire lighted	9-5	9-30	9-10	9-15	9-15	9-20
Test started	11-0	11-15	11-0	11-30	11-5	11-0
Test stopped	4-0	4-15	4-0	4-0	3-35	4-0
Duration of test—hours	5.0	5.0	5.0	4.5	4.5	5.0
Barometric pressure—ins	29.84	29.54	29.89	29.81	29.83	29.73
Pressure of air entering producer—ins. water	4.6	2.5	4.3	8.03	12.3	7.8
Pressure drop in air nozzle—ins. alcohol	1.38	.597	.954	1.26	1.116	1.67
Air temperature to nozzle—°F.	86	80.5	82	85	78	81
Atmospheric air—dry bulb—°F.	82	78.6	79	80	74.9	78.3
Atmospheric air—wet bulb—°F.	76	73.0	68.6	70.9	67.7	72.2
Humidity per cent	76	77	59	64	69	75
Air used per hour—cu. ft	885	585	734	860	808	985
Water in air per hr.—lbs	1.11	.666	.65	.857	.748	1.09
Water from tank per hr.—lbs	5.10	4.00	5.00	6.29	8.15	12.6
Water from coal per hr.—lbs	.07	.041	.013	.062	.066	.09
Total water to producer per hour—lbs	6.28	4.707	5.663	7.209	8.964	13.78
Water used per lb. coal—lbs.[14]	.85	.81	.895	1.05	1.345	2.29
Coal used per hour—lbs.[14]	7.42	5.81	6.33	6.86	6.66	6.0
Moisture in coal—per cent	0.9	0.7	0.2	0.9	1.0	1.5
Ash in coal—per cent	22.4	22.6	23.0	23.3	19.1	24.1
Gas Analysis: CO_2 per cent	9.3	11.0	9.9	11.0	11.7	11.0
(Average) O_2 "	.9	1.0	.9	1.0	.9	1.0
CO "	13.2	11.2	14.7	13.8	8.7	12.8
H_2 "	6.8	8.3	7.3	7.9	8.5	7.1
CH_4 "	1.5	.4	.3	.3	.6	.5
N_2 "	68.3	68.1	66.9	66.0	69.6	67.6
Higher Cal. Value—B.T.U./cu. ft	84.4	71.1	78.7	77.5	65.4	73.5
Lower Cal. Value—B.T.U./cu. ft	79.1	66.2	74.4	72.9	60.1	69.2

[14]Probably incorrect on account of accumulation of ash in fire.

TABLE 2—(*continued*)

Fuel	Peat Charcoal		Anthracite No.
Test No	14	15	16
Fire lighted	9-20	9-5	9-30
Test started	11-0	10-30	11-0
Test stopped	2-0	12-33	3-0
Duration of test—hours	3.0	2.05	4.0
Barometric pressure—ins	29.88	29.77	29.9
Pressure of air entering producer—ins. water	7.8	9.4	7.5
Pressure drop in air nozzle—ins. alcohol	1.70	1.77	1.735
Air temperature to nozzle—°F	82.1	83.3	77.7
Atmospheric air—dry bulb—°F	77.5	77.2	74.5
Atmospheric air—wet bulb—°F	73.2	73.2	69.0
Humidity per cent	82	83	80
Air used per hour—cu. ft	987	1012	1000
Water in air per hour—lbs	1.165	1.19	1.05
Water from tank per hour—lbs	12.17	13.35	7.60
Water from coal per hour—lbs	.794	1.01	.13
Total water to producer per hour—lbs	14.13	15.55	8.78
Water used per lb. coal—lbs	.982	.846	.995
Coal used per hour—lbs	14.42	18.37	8.81
Moisture in coal—per cent	5.5	5.5	....
Ash in coal—per cent	9.7	9.1	....
Gas Analysis: CO_2 per cent	9.8	11.7	10.5
(Average) O_2 "	1.5	1.0	1.0
CO "	16.8	13.8	12.4
H_2 "	12.0	14.5	7.2
CH_4 "	1.9	1.9	1.4
N_2 "	58.0	57.1	67.5
Higher Cal. value—B.T.U./cu. ft	119.0	117.2	82.1
Lower Cal. value—B.T.U./cu. ft	110.4	107.4	76.7

[15]Probably incorrect on account of accumulation of ash in fire.

Considerable difficulty was experienced (particularly in the tests made on Anthracite No. II) with the accumulation of ash in the fire, which obstructed the passage of the air blast, and in the case of tests Nos. 10 and 11, this was so serious that the tests had to be stopped, on account of the limited capacity of the blower. For this reason no tests were made on Anthracite No. II with air supplies exceeding 1000 cu. ft. per hour. The increase of resistance with accumulation of ash was reflected in the indications of the air pressure gauge and in some cases readings as high as 14 inches of water were obtained. This resistance is important in all cases, but is particularly so when the air is drawn through the producer by the suction stroke of the engine. Although the fire was poked every hour, it was found difficult to get rid of the ash, and if fuels containing 20% or more of ash are used it is probable that a grateless producer, with some means of discharging ash continuously and automatically, must be employed.

The very poor quality of gas produced over a wide range of air and water feed is noteworthy. It is known[16] that down draft producers generate poorer gas than those of the up draft type. In the present series of experiments only one test with anthracite gave an average calorific value (lower) exceeding 100 B.T.U. per cubic foot, and when attempts were made to reproduce the conditions with Anthracite No. II (tests 6 and 9) very poor results were obtained.

The comparatively high calorific value obtained in test No. 3 was due to the abnormal percentage of hydrogen present in the gas.

In all tests one sample of gas was taken each hour midway between poking times, and the analyses given in the table are the average percentages of each constituent. In this test individual figures for hydrogen varied from 18.0 to 22.9% and there is no doubt that the average figure given in the table represents the actual composition of the gas produced. It is curious, however, that even when the amount of water supplied was greatly increased (tests 12 and 13) it was found impossible to approach this figure. Test No. 19 was made for the purpose of ascertaining whether the distribution of water in the producer had any effect on the results obtained. For this test the water spray was placed in the air pipe in such a way as to get the maximum atomizing effect instead of being fed directly to the producer. This change produced no improvement.

The percentage of CO present in the gas is also low in all tests, and as in the case of hydrogen, does not appear to be greatly affected by changes in the rate of air or water supply over fairly wide ranges. The range of these experiments may be extended by using the smaller pro-

[16]See Rambush, "Modern Gas Producers," p. 314.

ducer linings, which will allow higher air velocities to be used with the same blower.

Experiments Nos. 14 and 15 show that peat charcoal is very suitable for this class of work, in fact much more so than the anthracite used. The tests were of short duration in these cases because of the small quantity of charcoal available. Even in this case, however, the quality of gas was not so high as that from an updraft producer working under similar conditions, and in view of the small percentage of volatiles in peat charcoal the peculiar advantages of downdraft producers do not apply to this fuel.

Unless a considerably better quality of gas can be obtained from bituminous fuels (and this is improbable), the results of these experiments indicate that the downdraft producer is unsuitable for traction work on account of

(*a*) the difficulty of keeping the fire clean,

(*b*) the large increase of resistance to the passage of air after running for a few hours,

(*c*) the poor quality of gas obtained.

The coal supplied to the hopper during each test was carefully weighed and the results are given in the table. It is probable, however, that these figures are considerably less than the actual fuel consumption in each case, as the accumulation of ash prevented some of the fuel from leaving the hopper. For this reason no efficiencies are tabulated, and the ratio of water to coal consumed is probably not correct. The range of the experiments, however, was such that the best ratio of water to fuel must have been used in some of the tests.

The possibilities of the downdraft producer, however, can hardly be said to be exhausted until further experimental work has been done on a grateless producer with bituminous fuels.[17]

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[17]A recent article in "Arts et Métiers" (March, 1926) describes producer gas driven trucks by Renault & Panhard respectively, the latter being a downdraft producer. Both machines use wood charcoal as fuel.

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